Quick Reference Information
Recommendations of the
National Council on Radiation Protection and Measurements

The information in this document is adapted, with the permission of the National Council on Radiation Protection and Measurements, from its publication *Management of Persons Accidentally Contaminated with Radionuclides, NCRP Report No. 65*. The material includes the publication's section 2, Quick Reference Information, as well as its table of contents to indicate additional information that is available.

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Contents

2. Quick Reference Information

TABLE 2.1—*On-site emergency check list*

Note: The sequence and priority of these actions will vary with different accident conditions.

- Provide emergency medical care immediately for serious injuries and preserve vital functions. Minor injuries can wait until after initial radiation survey has been completed.
- Remove individual from contaminated radiation area. Individual doses up to 100 rems may be permitted for life saving purposes or up to 25 rems for less urgent needs (NCRP, 1971). Teams may be used in relays to remove injured persons from very high radiation areas.
- Survey individual for surface contamination levels.
- Get nasal smears. Do this before showering (Sections 3.4.1 and 4.1.4).
- Remove contaminated clothes and replace with clean coveralls or wrap in blanket. Take individual to an area where skin decontamination or showering can be done.
- Decontaminate skin. Remove all transferable contamination if possible (Sections 3.7.4 and 7.1.5) by cleansing contaminated skin areas and showering.
- Cover contaminated wounds with sterile dressings before and after decontamination efforts (Section 7.2.5).
- Alert hospital and call for ambulance service as soon as it is determined that it is needed. Apprise them of situation if their help is required (Section 3.5.7).
- Identify radionuclide(s) involved in the accident and, if possible, ascertain its chemical form, solubility, and presumed particle size.
- Send personnel radiation dosimeters for processing.
- Get complete history of accident (Section 3.8.1), especially as it relates to the activities of the individual. Where was he? What was he doing? Exit path? Symptoms?
- Evaluate possibility of penetrating radiation exposure (Section 3.5.6).
- Advise individual on collection of all excreta (Section 3.5.8). Provide containers. Save other contaminated materials (Section 3.5.9).
- Be sure someone has assumed responsibility for management of the accident area. Is radiological assistance needed? Who will request it? From whom?
- Report your initial responses and evaluation to the plant manager (Section 3.5.4).
- Get names of supervisory and health physics personnel who will remain on call in case additional information is needed (Section 3.5.7).
- Take individual to the hospital if injuries require surgical care not available at plant or if further medical or dosimetric evaluation and treatment is required.
- Take precautions to prevent spread of contamination during transport and movement of the patient (Section 3.6). Have transport vehicles, attendants, and equipment checked for residual radioactive contamination before release from hospital area.
- If environmental contamination outside the plant has occurred, notify public health authorities (Section 3.9).
- Advise family and next of kin on the extent of injuries and exposure (Section 3.5.4). Plant management personnel and the medical department personnel should agree on the proper procedure.
- Find out where to send bioassay specimens and length of time required for analysis. Specify who will receive the results.

TABLE 2.2—*Identification tag information*

Note: Each patient should be identified with as much of the following accident and treatment information as is available before sending to decontamination center or hospital. Health physicist or company physician should keep in contact with the hospital to supply additional information as needed.

a. Name of patient, employer, company number.
b. Physical injuries and treatment.
c. Skin surface contamination: its location, dose rate and/or count rate measurements initially and after decontamination, and description of decontamination methods and agents used.
d. Internal contamination.
   (1) Radionuclide, its chemical form, probable solubility, and possible particle character.
   (2) Suspected route of contamination.
   (3) Nasal counts.
   (4) Wound counts.
   (5) Whole body counts.
   (6) Bioassay samples already collected.
   (7) Treatment initiated.
e. External exposure to penetrating, radiation.
   (1) Precise location and position of the patient relative to the source of radiation at time of exposure.
   (2) Exact time and duration of exposure.
   (3) Was dosimeter being worn? Where? What types?
   (4) Has dosimeter been collected? By whom? Where is it now located?
   (5) Symptoms; type and time of occurrence.
   (6) Describe other dosimetric studies underway.
   (7) Treatment.
f. Name and phone number of company health physicist or physician for additional information.

TABLE 2.3—*Medical identification check list*

Note: These questions can be used by the attending physician at the hospital for obtaining historical information to assist in the early management of radioactively contaminated persons. The best information in industrial cases can probably be obtained from plant personnel, such as the health physicist or occupational physician familiar with the plant and accident details.

- When did the accident occur? What are the circumstances of the accident-and what are the most likely pathways for exposure? How much radioactive material is involved potentially?
- What injuries have occurred? What potential medical problems may be present besides the radionuclide contamination?
- Are toxic or corrosive chemicals involved in addition to the radionuclides? Have any treatments been given for these?
- What radionuclides now contaminate the patient? Where? What are the radiation measurements at the surface?
- What information is available about the chemistry of the compounds containing the radionuclides? Soluble or insoluble? Any information about probable particle size?
- What radioactivity measurements have been made at the site of the accident, e.g., air monitors, smears, fixed radiation monitors, nasal smear counts, and skin contamination levels?
- What decontamination efforts, if any, have already been attempted? What success?
- Have any therapeutic measures, such as blocking agents or isotopic dilution been given?
- Was the victim also exposed to penetrating radiation? If so, what has been learned from processing personal dosimeters, e.g., film badge, TLD, or pocket ionization chamber? If not yet known, when is the information expected?
- Has clothing removed at the site of accident been saved in case the contamination still present on it is needed for radiation energy spectrum analysis and particle size studies?
- What excreta have been collected? Who has the samples? What analyses are planned? When will they be done?

TABLE 2.4—*Hospital decontamination procedures for protection of personnel and facilities*

- Personnel should wear surgical scrub suits, surgical caps and gowns, and rubber gloves (surgical, household, or industrial depending upon duties).
- The team leader should be trained to recognize the rare instance when there may be a need for masks, respirators, or supplied airpacks due to the prescense of high levels of alpha or beta radionuclides.
- Rubber or plastic shoe covers are desirable. Those performing the actual decontamination with water should wear plastic or rubber laboratory aprons. Good temporary shoe covers for dry areas can be improvised from brown paper bags held on with adhesive or masking tape.
- Air conditioning and forced air heating systems should be turned off so radioactive particulates are not carried into ducts or to other rooms unless a special filter system has been designed for use under these conditions.
- The floors should be protected with a disposable covering to reduce "tracking" by keeping cleaner surfaces and to aid the clean up tasks. The covering should be changed when significant contamination is present. Brown paper rolls (36 inches wide, 60-pound weight) are ideal where water is not used. Plastic sheets are useful where spillage of liquids is a problem, although ribbed or non-skid types should be used to reduce the chance of slips and falls.
- All contaminated clothing should be placed carefully into plastic or paper bags to reduce secondary contamination of area.
- Splashing of solutions used in decontamination should be avoided.
- Patients and other potentially contaminated personnel may move to clean areas only after surveys show satisfactory decontamination.
- All passage of persons and property between contaminated and clean areas must be surveyed and regulated by monitoring teams.
- Supplies are passed through monitoring stations from clean areas to contaminated areas. Reverse flow must not occur unless supplies are monitored and found clean.
- All individuals on the decontamination team shall be trained in radiological monitoring and decontamination techniques. Persons not working on the team should be excluded from the work area.
- Fiberboard or steel drums with tight fitting tops should be obtained for contaminated materials. Labels describing the contents should be affixed so that proper disposal can be carried out without reopening them. They may be sealed with masking tape or some other type of sealing tape.
- Personal dosimeters (pocket chambers, film, badge or TLD dosimeters) should be supplied to all personnel working in the decontamination area. Personnel should be rotated after a dose of 5 rems (or less if possible) is received.
- The entry of all non-essential personnel including family, visitors, and administrative persons should be restricted.

TABLE 2.5—*Treatment summary for selected elements*

The benefit from therapy recommendations in the Immediate Actions (Col. 2) and Drugs to Consider (Col. 3) columns will be influenced by the route of exposure—ingestion, inhalation, skin absorption, injection, or contaminated wounds. The chemical form and solubility of the radionuclide will also change markedly the efficacy of the recommended treatment. This table lists therapeutic procedures or drug therapy that may be helpful for the listed element in the favorable circumstances. The user is advised to consult the text for details on the influence of these other factors. The numbers in this table refer to sections in the text where additional information is available.

Element	Immediate actions	Drugs to consider	Information and comment
Americium (Am)	7.3.5.3–DTPA	7.3.5.3–DTPA	See Section 6.1. See Section 7.2 for contaminated wounds. Chelation should be started as soon as treatment decision can be made. CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.
Arsenic (As)	Consider 7.3.2.2–Lavage	7.3.5.4–Dimercaprol	Short-lived isotopes. Use of dimercaprol (7.3.5.4) is not indicated except in massive exposures.
Barium (Ba)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	See comment.	Use of sodium or magnesium sulfate with and after stomach lavage will precipitate insoluble barium sulfate.
Calcium (Ca)	Consider 7.3.2.2–Lavage 7.3.2.4–Purgatives and 7.3.3.6–Calcium	7.3.3.6–Calcium 7.3.4.4–Furosemide	Massive exposure may warrant use of the *sodium* salt of EDTA (7.3.5.2), but with caution over a 3-4 hour period to avoid tetany. Furosemide (7.3.4.4) enhances urinary excretion.
Californium (Cf)	7.3.5.3–DTPA Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	See Section 6.2. See Section 7.2 for contaminated wounds. Chelation should be started as soon as treatment decision can be made. CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.

TABLE 2.5—*Continued*

The benefit from therapy recommendations in the Immediate Actions (Col. 2) and Drugs to Consider (Col. 3) columns will be influenced by the route of exposure—ingestion, inhalation, skin absorption, injection, or contaminated wounds. The chemical form and solubility of the radionuclide will also change markedly the efficacy of the recommended treatment. This table lists therapeutic procedures or drug therapy that may be helpful for the listed element in the favorable circumstances. The user is advised to consult the text for details on the influence of these other factors. The numbers in this table refer to sections in the text where additional information is available.

Element	Immediate actions*	Drugs to consider*	Information and comment
Carbon (C)		No treatment available.	Soft beta rays of ^{14}C not detected by survey instruments; collect samples and smears for special low-energy beta counting in laboratory.
Cerium (Ce)	7.3.5.3–DTPA, Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	See Section 6.3. Chelation should start as soon as treatment decision is made. CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.
Cesium (Cs)	7.3.2.6–Prussian Blue, Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.2.6–Prussian Blue	See Section 6.4. Ion exchange resins (7.3.2.5) should be as effective as Prussian Blue, but have not been used in humans.
Chromium (Cr)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	No treatment available for anionic forms, 7.3.5.3–DTPA or 7.3.5.6–DFOA for cations.	Antacids are contraindicated. Adsorbents (such as charcoal or MgO_2) may reduce intestinal tract absorption.
Cobalt (Co)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	See comment.	See Section 6.5. Penicillamine (7.3.5.5) may be considered for therapeutic trial in large exposures.

Curium (Cm)	7.3.5.3–DTPA Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	See Section 6.6. See Section 7.2 for contaminated wounds. Chelation should start as soon as treatment decision is made. CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.
Europium (Eu)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	
Fission Products (Mixed)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	Depends on major isotope(s) in mixture, which varies with age of the isotope mixture.	Gamma-ray spectroscopy if plant air or swipe samples may identify prominent radionuclide(s) in mixture to determine definite therapy. Check also for possible alpha emitters. Most important nuclides may be iodine, cesium, cerium, and strontium.
Fluorine (F)	7.3.2.6–Aluminum hydroxide gel.	See comment.	Very short half-life. Oral aluminum hydroxide gel will reduce absorption from gastrointestinal tract.
Gallium (Ga)	See comment.	See comment.	Short half-life. Penicillamine (7.3.5.6) can be considered for therapeutic trial.
Gold (Au)		7.3.5.3–Dimercaprol and 7.3.5.5–Penicillamine are possible therapeutic agents.	See Section 6.7. No known thereapy for Au in colloidal form.
Hydrogen (H)			See Tritium.
Indium (In)		7.3.5.3–DTPA	Pharmaceutical form of indium is chelated already.

TABLE 2.5—*Continued*

The benefit from therapy recommendations in the Immediate Actions (Col. 2) and Drugs to Consider (Col. 3) columns will be influenced by the route of exposure—ingestion, inhalation, skin absorption, injection, or contaminated wounds. The chemical form and solubility of the radionuclide will also change markedly the efficacy of the recommended treatment. This table lists therapeutic procedures or drug therapy that may be helpful for the listed element in the favorable circumstances. The user is advised to consult the text for details on the influence of these other factors. The numbers in this table refer to sections in the text where additional information is available.

Element	Immediate actions*	Drugs to consider*	Information and comment
Iodine (I)	7.3.3.2–KI, Consider 7.3.2.2–Lavage	7.3.3.2–KI	See Section 6.8. Success of stable iodine (7.3.3.2) depends on early administration.
Iron (Fe)	Consider 7.3.2.2–Lavage and 7.3.2.10–Phytates	7.3.5.6–DFOA	Materials that reduce GI absorption include phytates (7.3.2.10), egg yolk, or adsorbents. Oral penicillamine (7.3.5.5) also chelates iron.
Lanthanum (La)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.
Lead (Pb)	Consider 7.3.2.2–Lavage	7.3.5.2–EDTA	Dimercaprol (7.3.5.4) and penicillamine (7.3.5.5) are less satisfactory alternative drugs.
Mercury (Hg)	Consider 7.3.2.2–Lavage	7.3.5.5–Penicillamine	See Section 6.9. Dimercaprol (7.3.5.4) may be considered for alternative therapy. Gastric lavage with egg white solution or 5 percent sodium formaldehyde sulfoxide; if unavailable, use a 2-5 percent solution of sodium bicarbonate.
Neptunium (Np)		See comment.	DTPA (7.3.5.3) may not be effective, but no other drugs are available.
Phosphorus (P)	Consider 7.3.2.2–Lavage and 7.3.2.7–Aluminum Hydroxide	7.3.3.4–Phosphates	See Section 6.10. Severe overdosage may be treated with parathyroid extract IM (7.3.4.6) in addition to oral phosphates (7.3.3.4).

Plutonium (Pu)	7.3.5.3–DTPA	7.3.5.3–DTPA	See Section 6.11. CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available, but is less effective. Chelation should be started as soon as treatment decision can be made. Desferrioxamine (7.3.5.6) may be used initially if DTPA is not available. See Section 7.2 for contaminated wounds.
Polonium (Po)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.4–Dimercaprol	See Section 6.12. Consider toxicity of Dimercaprol before using in cases of low-level exposure. Penicillamine (7.3.5.5) is an alternative treatment.
Potassium (K)	Consider 7.3.2.4–Purgatives, 7.3.4.4–Diuretics, 7.3.2.7–Aluminum Hydroxide	7.3.4.4–Diuretics	Use aluminum hydroxide antacids first to reduce GI tract absorption. Use oral liquid potassium supplements (7.3.3.8) for dilution.
Promethium (Pm)	7.3.5.3–DTPA Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	Chelation should be started as soon as treatment decision is made.
Radium (Ra)	7.3.2.4–Magnesium Sulfate Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	See comment.	See Section 6.13. Use 10 percent magnesium sulfate solution for gastric lavage and as saline cathartic. Oral sulfates (7.3.2.9) reduce intestinal absorption. No effective therapy after absorption. Ammonium chloride (7.3.4.3) and calcium (7.3.3.6) may increase urinary excretion slightly. Other agents that have shown little success include thyroid extract, parathyroid extract, and I.V. ACTH. Alginates are useful to reduce gastrointestinal absorption.

TABLE 2.5—*Continued*

The benefit from therapy recommendations in the Immediate Actions (Col. 2) and Drugs to Consider (Col. 3) columns will be influenced by the route of exposure—ingestion, inhalation, skin absorption, injection, or contaminated wounds. The chemical form and solubility of the radionuclide will also change markedly the efficacy of the recommended treatment. This table lists therapeutic procedures or drug therapy that may be helpful for the listed element in the favorable circumstances. The user is advised to consult the text for details on the influence of these other factors. The numbers in this table refer to sections in the text where additional information is available.

Element	Immediate actions	Drugs to consider	Information and comment
Rubidium (Rb)	7.3.2.6–Prussian Blue	7.3.2.6–Prussian Blue	Chemical properties are similar to potassium, but efficacy of similar treatments is unknown.
Ruthenium (Ru)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	See comment.	Chlorthalidone (7.3.4.4) causes enhanced urinary excretion, DTPA (7.3.5.3) has variable effectiveness.
Scandium (Sc)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	7.3.5.3–DTPA	EDTA (7.3.5.2) may be used in place of DTPA.
Silver (Ag)			Short effective half-life. No therapy.
Sodium (Na)	Consider 7.3.2.2–Lavage	7.3.4.4–Diuretic	Isotopic dilution (1 liter I.V. - 0.9 percent NaCl) by I.V. route followed by furosemide or other diuretic agents (7.3.4.4).
Strontium (Sr)	7.3.2.7–Aluminum Phosphate (7.3.2.4–Magnesium Sulfate or 7.3.2.8– Alginates are alternatives) Consider 7.3.2.2–Lavage	7.3.3.3–Strontium or 7.3.3.6 (Calcium I.V.) and 7.3.4.3 (Ammonium chloride)	See Section 6.14. Corticosteroid (7.3.4.7) may be considered, but adverse reactions should be balanced against probable limited effectiveness.

Sulfur (S)	Consider 7.3.2.2–Lavage and 7.3.2.4–Purgatives	No therapy known.	Soft-energy beta rays of ^{35}S not detectable with conventional survey instruments. A thin window survey meter may be used or obtain smears or samples for special low-energy beta counting in laboratory.
Technetium (Tc)			See Section 6.15. Potassium perchlorate has been used effectively to reduce thyroid dose.
Thorium (Th)		DTPA (7.3.5.3) or DFOA (7.3.5.6) useful for soluble compounds.	See Section 6.16. Treatment not effective for thorotrast (ThO_2).
Tritium (^3H)	7.3.3.5–Forced water	7.3.3.5–Forced water	See Section 6.17. Soft-energy beta rays of ^3H, not detectable by survey instrument, require samples for special low-energy beta counts in laboratory.
Uranium (U)	7.3.5.3–DTPA		See Section 6.18. DTPA must be given within 4 hours to be effective. Sodium bicarbonate protects kidney from damage.
Yttrium (Y)		7.3.5.3–DTPA	CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.
Zinc (Zn)	Consider 7.3.2.2–Lavage. Phytates (7.3.2.10) may reduce intestinal uptake.	7.3.5.3–DTPA	Zinc sulfate (7.3.3.7) may be used as diluting agent if CaDTPA is not immediately available. CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available. Penicillamine (7.3.5.5) is a second alternative for DTPA.
Zirconium (Zr) -Niobium (Nb)	Consider 7.3.2.2–Lavage	7.3.5.3–DTPA	CaEDTA (7.3.5.2) may be used if CaDTPA (7.3.5.3) is not immediately available.

2. QUICK REFERENCE INFORMATION / 15

TABLE 2.6—*Information on selected radionuclides**

(1) Nuclide	(2) Radiation	(3) Rhm per curie	(4) Measurement methods		(5) Half-life		(6) MPBB µCi	(7) Critical organ[a]	(8) Dose (rem/µCi in organ)			
									Critical organ		Lung (Inhalation)	
			External	Internal	Physical	Effective			13 week	50 yr	13 week	50 yr
Americium-241	alpha, gamma	0.01	A, BG(SP), S	IVC,F,NS,U	458 yr	139 yr	0.05	Bone	190	30,000	250	2100
Americium-243	alpha, gamma, D	0.02	A, BG(SP), S	IVC,F,NS,U	7950 yr	195 yr	0.05	Bone	180	30,000	240	2000
Arsenic-74	beta, gamma	0.42	BG, S	BC, NS	18 d	17 d	--	Total body	0.009	0.01	0.36	0.36
Arsenic-77	beta, gamma, D	0.006	BG, S	BC, NS	39 h	24 h	--	Total body	0.0004	0.0004	0.028	0.028
Barium-140	beta, gamma, D	0.14	BG, S	BC, N, S, U	13 d	11d	--	Bone	0.49	0.49	1.3	1.3
Cadmium-109	gamma, D	0	BG(S), S	F, U	453 d	140 d	20	Liver	0.19	0.53	0.36	1.5
Calcium-45	beta	--	BG, S	U	165 d	162 d	30	Bone	0.24	0.74	0.20	0.24
Calcium-47	beta, gamma, D	0.54	BG, S	BC, NS, U	4.5 d	4.5 d	--	Bone	0.12	0.12	0.25	0.25
Californium-252	gamma, alpha, neutron, D	--	A, BG, S	BC, U, NS	2.6 yr	2.2 yr	0.01	Bone	710	11,000	890	5100
Carbon-14	beta	--	S(LS), BG(SP)	U, F, B(CO_2)	5730 yr	12 d	--	Total body	0.0006	0.0006	0.14	0.20
Cerium-141	beta, gamma, D	0.033	BG, S	BC, F, NS, U	32 d	30 d	--	Liver	0.29	0.23	0.36	0.41
Cerium-144	beta, gamma, D	0.008	BG, S	BC, F, NS, U	284 d	280 d	5	Bone	3.7	16	5.1	17
Cesium-137	beta, gamma, D	0.32	BG, S	BC, F, NS, U	30 yr	70 d	--	Total body	0.03	0.04	1.1	1.5
Chromium-51	gamma	0.018	BG, S	BC, F, U	28 d	27 d	--	Total body	0.0006	0.0007	0.025	0.027
Cobalt-57	gamma	0.093	BG, S	BC, F, U	270 d	9 d	--	Total body	0.0009	0.0009	0.13	0.16
Cobalt-58	beta, gamma	0.54	BG, S	BC, F, U	71 d	8 d	--	Total body	0.005	0.005	0.55	0.62
Cobalt-60	beta, gamma	1.3	BG, S	BC, F, U	5.3 yr	10 d	--	Total body	0.015	0.015	1.9	2.6
Curium-242	alpha, neutron, gamma	--	A, BG, S	BC, F, U	163 d	155 d	0.05	Liver	180	540	230	580
Curium-243	alpha, gamma	0.041	A, BG, S	BC, F, U	32 yr	27.5 d	0.09	Liver	160	15,000	260	2100
Curium-244	alpha, neutron, gamma	--	A, BG, S	BC, F, U	17.6 yr	16.7 yr	0.1	Liver	160	11,000	260	2100
Europium-152	beta, gamma, D	0.53	BG, S	BC, F, U	13 yr	3 yr	20	Kidney	3.8	69	1.4	11
Europium-154	beta, gamma	0.63	BG, S	BC, F, U	16 yr	3 yr	5	Bone	1.8	34	3.7	29
Europium-155	beta, gamma	0.021	BG, S	BC, F, U	2 yr	1.3 yr	70	Kidney	1.2	9.3	0.4	1.9
Fission Products	beta, gamma	--	BG, S	BC, F, NS, U	--	--	--	--	--	--	--	--
Fluorine-18	beta, gamma	0.56	BG, S	BC	2 h	2 h	--	Total body	0.00007	0.00007	0.003	0.003
Gallium-72	beta, gamma	1.16	BG, S	BC	14 h	12 h	--	Liver	0.024	0.024	0.047	0.047
Gold-198	beta, gamma	0.23	BG, S	BC, F, U	2.7 d	2.6 d	--	Total body	0.001	0.001	0.087	0.087
Hydrogen-3 (Tritium)	beta	--	BG(SP), S(LS)	U	12 yr	12 d	--	Total body	0.0002	0.002	--	--
Indium-114m	beta, gamma, D	0.042	BG, S	BC	49 d	27 d	--	Kidney, spleen	5.6	6.2	1.6	1.7
Iodine-125	beta, gamma	0.07	BG, S	BC, IVC, U	60 d	42 d	--	Thyroid	4.2	5.4	--	--
Iodine-131	beta, gamma, D	0.21	BG, S	BC, IVC, U	8 d	8 d	--	Thyroid	6.5	6.5	--	--
Iron-55	gamma	--	BG, S	F	2.6 yr	1 yr	1000	Spleen	0.19	1.2	0.016	0.023
Iron-59	beta, gamma	0.63	BG, S	BC, F	46 d	42 d	--	Spleen	5.5	7.0	0.69	0.74
Lead-210	beta, gamma, D	0.002	BG, S	F, U, IVC	20 yr	1.3 yr	0.4	Kidney	150	1200	66	92

[a]See column explanations on pages 18 and 19.

TABLE 2.6—*Continued*

(1) Nuclide	(2) Radiation	(3) Rhm per curie	(4) Measurement methods		(5) Half-life		(6) MPBB µCi	(7) Critical organ[a]	(8) Dose (rem/µCi in organ)			
									Critical organ		Lung (Inhalation)	
			External	Internal	Physical	Effective			13 week	50 yr	13 week	50 yr
Mercury-197	gamma	0.037	BG, S	BC, U	2.7 d	2.3 d	--	Kidney	0.022	0.022	0.009	0.009
Mercury-203	beta, gamma	0.013	BG, S	BC, U	46 d	11 d	--	Kidney	0.30	0.30	0.30	0.31
Molybenum-99	beta, gamma, D	0.076	BG, S	BC, NS, F, U	2.8 d	1.5 d	--	Kidney	0.17	0.17	0.094	0.094
Neptunium-237	beta, gamma, D	0.017	A, BG, S	BC, U	2×10^6 yr	200 yr	0.06	Bone	170	28,000	220	1800
Neptunium-239	beta, gamma	0.05	A, BG, S	BC, U	2.3 d	2.3 d	--	GI(LLI)	0.023	0.023	0.027	0.027
Phosphorus-32	beta	--	BG, S	BC, U	14 d	14 d	--	Bone	0.10	0.10	0.56	0.56
Plutonium-238	alpha, gamma	0.001	A, BG(SP)	IVC, F, NS, U	88 yr	63 yr	0.04	Bone	190	26,000	250	2100
Plutonium-239	alpha, gamma	<0.001	A, BG(SP)	IVC, F, NS, U	2.4×10^4 yr	197 yr	0.04	Bone	180	30,000	230	2000
Polonium-210	alpha	<0.001	A	U, F	138 d	46 d	--	Spleen	880	1100	120	150
Potassium-42	beta, gamma	0.14	BG, S	BC, U	12 h	12 h	--	Total body	0.00	0.00	0.056	0.056
Promethium-147	beta	--	BG, S	F, U, NS	2.6 yr	1.6 yr	60	Bone	0.22	2.2	0.29	1.7
Promethium-149	beta, gamma	0.004	BG, S	F, U, BC, NS	2.2 d	2.2 d	--	Bone	0.044	0.044	0.071	0.071
Radium-224	alpha, gamma, D	--	A, BG	BC	3.6 d	3.6 d	--	Bone	11	11	70	70
Radium-226	alpha, gamma, D	0.825	A, BG, S	BC, B	1600 yr	44 yr	0.1	Bone	73	10,000	290	410
Rubidium-86	beta, gamma	0.05	BG	BC, F, U	19 d	13.2 d	--	Total body	0.009	0.009	0.66	0.66
Ruthenium-106	beta, D	0.11	BG	BC, F, U	368 d	2.5 d	--	Kidney	0.80	0.80	5.6	22
Scandium-46	beta, gamma	1.1	BG	BC, F, U	84 d	40 d	--	Liver	0.64	0.70	1.3	1.5
Silver-110m	beta, gamma, D	1.4	BG	BC, U	255 d	5 d	--	Total body	0.008	0.008	3.3	0
Sodium-22	beta, gamma	1.2	BG	BC, U	950 d	11 d	--	Total body	0.018	0.018	0.0012	0.001
Sodium-24	beta, gamma	1.8	BG, S	BC, U	15 h	14 h	--	Total body	0.0017	0.0017	0.0023	0.002
Strontium-85	gamma	0.3	BG, S	BC, U, F	65 d	65 d	--	Total body	0.014	0.022	0.30	0.33
Strontium -90	beta, D	--	BG, S	U, IVC, F	28 yr	15 yr	2	Bone	3.6	320	2.9	4.1
Sulfur-35	beta	--	BG(SP), S(LS)	F, U	88 d	44 d	--	Testis	22	40	0.00008	0.00008
Technetium-99m	gamma	0.059	BG, S	BC, NS, U	6 h	5 h	--	Total body	0.00001	0.000011	0.00064	0.00064
Technetium-99	beta	--	BG, S	U	2×10^5 yr	20 d	--	Kidney	0.12	0.13	0.09	0.13
Thorium-230	alpha, gamma	--	A, BG, S	BC, IVC, F, U	8×10^4 yr	200 yr	0.05	Bone	160	29000	210	1800
Thorium-232	alpha, gamma, D	--	A, BG, S	BC, IVC, F, U	1.4×10^{10} yr	200 yr	0.04	Bone	180	33000	210	1800
Thorium-Natural	alpha, beta, gamma	--	A, BG, S	BC, IVC, F, U	--	200 yr	0.01	Bone	180	33000	200	1700
Tritium (see Hydrogen-3)	--	--	--	--	--	--	--	--	--	--	--	--
Uranium-235[b]	alpha, gamma, D	--	A, BG	BC, IVC, U	7.1×10^8 yr	15 d	--	Kidney	170	170	200	1700
Uranium-238	alpha, gamma, D	--	A, BG	BC, IVC, U	4.5×10^9 yr	15 d	--	Kidney	160	160	190	1600
Uranium-Natural	alpha, beta, gamma	--	A, BG	BC, IVC, U	4.5×10^9 yr	15 d	--	Kidney	170	170	200	1700
Yttrium-90	beta	--	BG, S	U	64 h	64 h	--	Bone	0.12	0.12	0.17	0.17
Zinc-65	beta (+), gamma	0.3	BG, S	BC, U	245 d	194 d	60	Total body	0.018	0.066	0.36	0.46
Zirconium-95	beta, gamma, D	0.4	BG, S	BC, U	66 d	56 d	--	Total body	0.003	0.003	0.97	1.09

[a]See column explanations on pages 18 and 19.

[b]For measurement of enriched uranium exposures, the ^{234}U activity must be ascertainied in addition to ^{235}U.

COLUMN EXPLANATIONS FOR TABLE 2.6

Information on selected radionuclides

Column (1) *Nuclide.* The name of the element and the atomic mass of the particular isotope are listed alphabetically by element.

Column (2) *Radiations.* The primary radiations are listed. For simplicity, some liberties have been taken in listing the radiations.

Beta refers to both positron and electron emission.

Gamma includes conversion x-ray emissions as well as gamma rays. The letter D refers to the possible presence of daughters with a half-life of less than 25 years. The radiations of the daughters are not included in the listing.

Column (3) *Rhm per Ci.* Roentgens per hour at 1 meter from 1 curie. These values are only approximate. A dash in the column indicates that the number was not evaluated because daughter radiations contribute appreciably to the gamma dose rate; because of an uncertain or complex decay scheme; or because the isotope emits no appreciable gamma radiation, as in the case of pure beta emitters.

Column (4) *Measurement Methods.* The following symbols are used to indicate principal techniques for measuring external contamination or indicating internal exposure. The order of the symbols has no significance in the listing.

External: A–Alpha counting techniques.

BG–Beta-gamma counting and detection techniques. Start all monitoring with detector unshielded.

BG(Sp)–Special attention necessary to select appropriate low-energy monitoring techniques.

S-Smear or swipe sample counted in laboratory.

S(LS)–Liquid scintillation counting of samples.

Internal: BC–Whole body count (standard gamma detection methods), including nuclear medicine counters.

F–Feces sample analyses.

IVC–Special in vivo counting techniques useful for low-energy counting, e.g., wound-monitoring, thyroid counting, or special low-energy x-ray or gamma detectors for chest counts, e.g., plutonium or americium counting.

NS–Nose swipe counted in laboratory if inhalation suspected.

U–Urine sample analyses.

B–Breath analysis for gases.

Column (5) *Half-Life.* The radioactive and the effective half-lives are taken from ICRP (1960), except for the transuranic elements which were taken from ICRP (1972).

Column (6) *MPBB.* The maximum permissible body burden (MPBB) is listed for those radioisotopes with effective half-lives in excess of 120 days. For isotopes with shorter effective half-lives, the estimated dose to the critical organ is more meaningful for emergency decisions (see Column 8). The MPBB is based on a life-time continued exposure under conditions in which an equilibrium is established, or at least approached between intake and elimination. It should not be used in the sense implied in this table for a single exposure situation.

Column (7) *Critical Organ.* The organ that receives the highest dose or has the most

significant biological effect. Only one organ has been listed for each radioisotope. This is an artificial representation since different chemical forms and modes of exposure will determine the critical organ; this table is intended to give only a limited presentation on one principal organ at risk until more complete information can be obtained.

Column (8) *Dose.* An approximate dose equivalent in rem is calculated for 1 microcurie of the radionuclide in the *critical organ* (Column 7) or lung, in the case of inhalation, after 13 weeks and 50 years residence time in that organ. These are approximate values to assist in rapid dose estimates if body (or organ) burden can be estimated. They are not definitive dose determinations particularly since they do not take into account the radionuclide distribution in the total body to the listed critical organ. Thus the physiological chemistry and solubility of the material involved in an actual exposure is not taken into account in this table. The curie for isotopes with radioactive daughters is defined as 3.7×10^{10} disintegrations per second of the parent only. Thus a curie of natural uranium includes only the activity of the ^{238}U parent and not activity of the daughter such as ^{234}U.